

attention states this amount for the different colours. If we use a piece of quartz so thick that it rotates any particular tint just 90° , that tint will be cut off by the crossed analyzer, and all others will—in greater or less proportion—be transmitted, so that the resulting tint will be complementary to that cut off. For example, a slice just so thick as to twist yellow waves round 90° must be 3.75 millimetres thick. (I may remark, for the benefit of those who think it easier to express this exact thickness in fractions of a British inch, that the quartz which rotates yellow light 90° must have a thickness equal to one-eighth, plus three-sixteenths of an eighth, plus one sixty-fourth of an eighth of an inch.) When such a quartz is placed between the crossed Nicols, the light shown is yellow; but if placed between parallel Nicols (*i.e.* in the bright field), it shows a rich purplish-violet colour, the complementary of the yellow. This particular tint Biot found to be excessively sensitive, the smallest inaccuracy in adjustment between the prisms at once producing a change, the colour appearing too red or too blue, according to the direction in which the analyzer has been turned out of exact adjustment. This tint is accordingly known as the “transition tint” or “sensitive tint,” its accurate definition being due to the fact that the human eye is more sensitive to the presence or absence of the complementary yellow than to any other tint in the whole spectrum. If we take, however, a quartz plate twice as thick as this—namely, 7½ millimetres thick—this will give the yellow light a torsion of 180° . Hence this gives the purple transition tint in the dark field, and is yellow in the bright field. A quartz plate 11¼ millimetres thick gives again a transition tint in the bright field. I shall recur presently to the question of the transition tints of the several orders.

One of the familiar facts in this subject is that there are two kinds of quartz crystals, optically alike in every other respect, differing only in this, that one kind produces a right-handed twist, the other kind a left-handed twist. All the pieces of quartz I have so far employed are right-handed specimens. I now introduce two small slices of crystal, each 3¼ millimetres thick, giving the yellow tint when the Nicols are exactly crossed, but you will notice that when we are using the right-handed crystal, the tint grows reddish as the analyzer is turned towards the left, and greenish when the analyzer is turned towards the right; whereas, when I substitute the left-handed slice, the tint grows greenish as the analyzer is turned toward the left, and reddish when it is turned toward the right. If the analyzer is turned through an exact right-angle, we get an extinction of the yellow light, the remaining blue and red rays combining to give us the purple transition tint.

You will have noticed that the way in which we have (approximately) measured the angle of rotation has been first to set the analyzer to extinction, then to introduce the substance which has the property of rotating the beam, then to turn the analyzer again to extinction, and read off its angle. For, of course, the angle through which the analyzer is turned measures the angle through which the plane of polarization has been turned.

It is possible, however, to show in the lantern something like a more obvious rotation of the light by introducing between the Nicols a crystal star, built up of radial pieces of mica, twenty-four in number (Fig. 8). You see in the bright field a white cross with black sectors at 45° . Or, in the dark field we have a black cross with vertical and horizontal arms, the sectors next to those that are black seeming dusky. If now I put in a quartz plate between the star and the analyzer, you see the cross shift round, and it shows colours, because the blue rays are twisted round more than the green, the green than the yellow, the yellow than the red. Repeating the experiment with the 3.75 millimetre quartz which turns yellow waves round just 90° , we get this gorgeous radiation of colours, and our black cross is turned into a yellow one. With the 7.5 millimetre quartz, the black cross is replaced by one of “transition” tint.

The black crosses seen in certain sections of natural crystals, sphæroliths, sections of stalactites, crystallizations of salicine and of Epsom salts, may also be used instead of the 24-rayed star of mica. But best of all I find to be the beautiful black cross which is seen by polarized light in the prepared crystalline lens taken from the eye of a fish. You notice how, when the fish lens is projected and the quartz introduced, the cross turns round.

This is, however, a rough-and-ready way of displaying the rotation, and it is of vast practical importance that precise methods of measuring the angle of rotation should be available—of vast

importance, because in several large industries this optical method is applied as a species of handy analysis. I have named a solution of sugar as being an “active” substance. In the industry of sugar-refining, as in that of brewing, the strength of sugar in the liquids is directly measured by measuring its optical effect. Consequently there has been developed a special instrument, the *polarimeter*, for this express purpose.

I have here examples of several practical forms of polarimeters; there are diagrams of several more upon the walls.

The problem of finding the best polarimeter naturally leads to the inquiry what special means are there for making the observation of the angle more precise than by merely observing the extinction of the light, its restoration when the active substance is interposed and the subsequent renewal of extinction when the analyzing prism is turned.

Biot considered that much greater accuracy could be attained by watching for the restoration of the sensitive tint than by

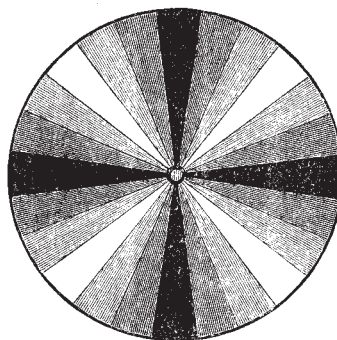


FIG. 8.—Mica disk of twenty-four rays, showing black cross in the dark field.

watching for the mere restoration of extinction of the light. Accordingly we will use the plate of quartz 7.5 millimetres thick, giving the purple tint, to enable us to measure the rotation produced by the tube of sugar solution which is now inserted in the beam of polarized light. You notice how the tint has changed. But I have only to turn the analyzer to an amount equal to that to which the light has been twisted by the sugar, and again I obtain the sensitive transition tint.

The eye is not always, however, alive to minute changes of colour in a single coloured patch; it much more readily distinguishes a minute difference between two tints when both are present at once. Hence Soleil devised the well-known bi-quartz arrangement, consisting of two pieces of crystal, equal in thickness but possessing opposite rotations. You will notice how the slightest inaccuracy in placing the analyzer causes the two halves of the field to differ in tint. This is especially marked when the tint chosen is the transition purple.

(To be continued.)

THE PLANET URANUS.

THAT anomalous section of the solar system, Uranus and its satellites, offers yet a wide field of investigation to astronomical specialists of all kinds. Its figure, its rotation, satellites, and physical constitution altogether, are moot points, which should be more or less settled with the increased optical power now at our disposal.

The circumstances attendant upon the discovery of Uranus in 1781 (Phil. Trans., 1781, p. 492) are matters of common knowledge. The planetary nature of the supposed comet seems to have been first suspected by Maskelyne, and it was this suggestion that induced Lexell to calculate for it a circular orbit in 1781 (Grant's "History of Physical Astronomy," p. 274). The elliptic elements of the planet were first calculated by Laplace in 1782 (*Mém. Acad. des Sciences*, Paris, January 1783).

The first measures of the Uranian diameter were singularly incongruous. Herschel found it in March 1781 to be $2''.53$; whilst in the following month he measured it as $4''.52$ and $5''.2$, (Phil. Trans., 1781, p. 494). A like discordance occurred in the results obtained by other astronomers. Maskelyne fixed the magnitude of the apparent diameter as $3''$, whilst Mayer, of

Manheim, estimated it to be as high as $10''$ (Grant's "History of Astronomy," p. 275).

The difference between these measures of the diameter of Uranus would seem to be a consequence of the fact that it is always extremely difficult to get the planet clearly defined in the field of the telescope. Herschel himself noted (Phil. Trans., 1798, p. 69), "The Georgian planet is not so well defined as, from the extraordinary distinctness of my present 7-feet telescope, it ought to be. There is a suspicion of some apparatus about the planet."

Herschel several times had the impression that Uranus was surrounded with a ring. One of his observations is contained in the following (Philosophical Transactions, 1798, p. 68):—"My telescope is extremely distinct, and when I adjust it upon a very minute double star, which is not far from the planet, I see a very faint ray, like a ring crossing the planet, over the centre. This appearance is of an equal length on both sides, so that I strongly suspect it to be a ring. . . . I have turned the speculum one quadrant round, but the appearance of the very faint ray continues where it was before, so that the defect is not in the speculum nor is it in the eye-piece." Later observations, however, led Herschel to conclude "that Uranus has no ring in the least resembling that, or rather those, of Saturn."

Following upon the observations as to the existence of a ring round Uranus, are found others relating to its polar compression. The flattening at the poles was first observed by Herschel in February 1794 (Phil. Trans., 1798, p. 69), and announced in the following words: "The planet seems to be a little lengthened out, in the direction of the longer axis of the satellite's orbit;" and again in April of the same year: "The disk of the planet seems to be a little elliptical." Mädler measured the ellipticity in 1843, and found it $1/9.92$ (Grant's "History of Astronomy," p. 278). Schiaparelli, in 1883, using two different methods, obtained the results $1/10.98$ and $1/10.94$ (*Astr. Nach.*, No. 2526). A few measures made by Young in the same year gave an ellipticity $1/14$ ("General Astronomy," Young, p. 367). The fact that the ellipticity was in the same plane as the major axis of the satellite's orbit led Herschel to conclude from analogy with Jupiter and Saturn, "That the Georgian planet also has a rotation upon its axis of a considerable degree of velocity" (Phil. Trans., 1798, p. 71). Other observers of the bulging out of the Uranian equator—Schiaparelli, Young, Safarik—agree with Herschel in saying that the plane is coincident with that of the satellite's motion, but the following observations of markings on the surface of Uranus lead to an entirely different conclusion.

Buffham noticed some bright markings on Uranus in 1870-72 (*Monthly Notices*, vol. xxxiii. p. 164), and, from observations of their motion, deduced the time of rotation as twelve hours, but the plane of rotation was not coincident with that of the satellite's orbit. This was borne out by observations of dusky bands by Young, in 1883 ("Princetown Observations," 1883); of apparent equatorial belts by the brothers Henry, in 1884 (*Comptes rendus*, t. xcvi. p. 1419); and observations in 1884, at Nice, of a bright spot by Lockyer, Perrotin, and Thollon (*Comptes rendus*, t. xcvi. pp. 717, 967). The plane of rotation, according to these observers, is from 15° to 40° from the trend of the satellite's. Thus the difference between the two sets of observations amounts to nearly half a right angle. Does the error lie in the observation of the belts, or in the measurements of the planet's ellipticity and the satellite's orbit? This is an enigma which yet remains to be solved, and another character of Uranus requiring investigation.

Herschel made the first determination of the mass of Uranus in 1788 (Philosophical Transactions, 1788, p. 369), and found it to be 17.740612 as compared with the earth, or about $1/18,000$ that of the sun. Bouvard found a value $1/17,918$; Lamont, in 1837, $1/24,605$. Lassell's observations of the motion of the satellites gave a value $1/20,897$, whilst Struve's observations gave a value $1/26,860$. The mass, $1/22,600$, found by Newcomb ("Washington Observations," 1873), is probably the most correct, and he estimates that the probable error in the denominator is not more than 100. This mass, revolving round the sun at a mean distance of about 1800 millions of miles, must exert considerable influence upon bodies near it, influence which may often predominate over that of the sun.

But it is the question of Uranian satellites that is so enigmatical. Herschel discovered two on January 11, 1787 (Phil. Trans., 1787, p. 125 *et seq.*), and in 1798 announced the discovery of four more. Regarding the real existence of these four, Herschel remarks (Phil. Trans., 1798, p. 66): "It remains now

only to be mentioned that, in such delicate observations as these of the additional satellites, there may possibly arise some doubts with those who are very scrupulous; but as I have been much in the habit of seeing very small and dim objects, *I have not been detained from publishing these observations sooner, on account of the least uncertainty about the existence of these satellites*, but merely because I was in hopes of being able soon to give a better account of them, with regard to their periodical revolutions."

Sir John Herschel observed the two brightest satellites between 1828 and 1832 (Mem. Ast. Soc., vol. viii. p. 1); but "of other satellites," he says, than these, "I have no evidence," although the telescope he was using was precisely similar to that used by his father. A systematic search was made by Lassell for the lost satellites, and a definite announcement of the discovery of two satellites between Uranus and the two brightest was made in 1851 (*Monthly Notices R.A.S.*, xi. 248). He declares, however, that it would have been impossible for Sir William Herschel to have seen these two faint bodies; and although Prof. Holden has attempted to identify the two with two of Herschel's quartett, the balance of evidence is certainly to the contrary, and we are bound to conclude that no one has ever seen the four but Herschel himself.

Herschel announced, in 1798 (Phil. Trans., 1798, p. 48), the retrograde movements of the Uranian satellites in the terse paragraph, "I take this opportunity of announcing that the movement of the Georgian satellites is retrograde." The fact that their orbits were inclined about 80° to the ecliptic plane was discovered in 1788.

Herschel also particularly noticed that the light of the two brightest satellites was subject to considerable fluctuations, and in 1815 (Phil. Trans., 1815, p. 356) he suggests for a cause that given by Newton in the "Principia" to account for the periodical variability of certain stars. His conclusion was:—"The variable brightness of the satellites may be owing to a rotation upon their axes, whereby they alternately present different parts of their surface to our view. These variations may also arise from their having atmospheres that occasionally hide or expose the dark surface of their bodies, as is the case with the sun, Jupiter, and Saturn."

The two inner satellites, Ariel and Umbriel, discovered by Lassell, seem also to fluctuate in brightness, and Newcomb observed in 1875 ("Washington Observations," 1873, p. 43):—"I strongly suspect that Ariel, at least, belongs to that class of satellites of which the brilliancy is variable and dependent on its position in its orbit. The evidence of variability of some kind seems indisputable, as I have repeatedly failed to see it when the circumstances, distance from the planet included, were in every respect favourable, and when Umbriel, though less favourably situated, was visible. On the other hand, there were two occasions, January 28, 1874, and March 25, 1875, when it was surprisingly conspicuous. Unfortunately no systematic record was made of the times when, being near greatest elongation, it was looked for and not seen; but on at least one such occasion its position angle was 180° . An inspection of the observations shows that out of the eight observations only two were made near the southern elongation; while in the two cases where its brightness was most remarkable, the position angles were respectively 348° and 351° ."

The time of revolution of Ariel is 2.520378 days at a mean distance of 120,000 miles; its diameter is about 500 miles.

Herschel also observed that these satellites became invisible some distance from the planet's disk (Phil. Trans., 1798, p. 75); thus, on February 22, 1791, the first satellite was lost when $22''$ from the planet. This distance was not, however, constant, for on May 2, 1791, the same satellite disappeared at an apparent distance $19''.8$. A table is given showing at what distance from the planet the first and second satellites respectively became invisible during a period of seven years. A fact exhibited by this table is that the distance at which the satellites disappeared regularly diminished from 1791 to 1797, until in the latter year the first satellite was traced to $4''.8$ from the planet's disk. The reason assigned to account for this phenomenon by Herschel was that the light of the satellites was "put out" by the stronger light of their primary, and regarding this he remarks (Phil. Trans., 1798, p. 78):—"We may avail ourselves of the observations that relate to the distances at which the satellites vanish, to determine their relative brightness. The second satellite generally appears brighter than the first; but as the former is usually lost farther from the planet than the latter we may admit

the first satellite to be rather brighter than the second." The diameters of the first and second satellites are about 1000 and 800 miles respectively, hence Herschel's comparative measures were correct.

R. A. GREGORY.

BABYLONIAN ASTRONOMY.¹

I.

CLASSICAL writers seem to be unanimous in considering the Babylonians as the most ancient astronomers; a close examination shows, however, that the statement emanated from one or two writers, and that all the others merely repeated it without taking the trouble of verifying it. The figures given by various authors as to the period covered by the Babylonian astronomical observations are most extravagant, but the disagreement of the authors proves their inaccuracy. In spite of all discrepancies, one fact comes out clearly—that is, the Semitic origin of the Babylonian astronomy. Belus, the eponymic king of Babylon, considered by the classics as the first ruler or even the colonizer of Babylonia, is called the "inventor of astronomy," and Seneca considered the work of Berosus as a translation of that of Belus.

If we turn now to the native documents—the tablets now in the British Museum—we can class them under two distinct periods, those previous to the Greek rule and those contemporaneous with the Seleucids. Some tablets of the first period give us lists of certain astronomical or atmospheric observations, with the events which took place at the same time; the others are mere reports of the official astronomers stating what they observed, as the occurrence or non-occurrence of an eclipse. A characteristic point is that the observations are in no case dated: the day and the month are, indeed, given, but not the year; and this leaves no doubt as to the real character of these documents.

The Babylonians held the belief that the sky was a reflection of what was going on upon the earth: if, therefore, a certain event took place at the time of the conjunction of two stars, the same event would repeat itself when the same conjunction would take place. There were no predictions, but merely statements of real facts taking place at the same time in the sky and upon the earth, the actual date of which was of no consequence, as the object in view was to establish the supposed connection between what happened in the sky and what happened upon the earth—in short, correlative events. It appears also that the Babylonians admitted the existence of a cosmical year—that is, a period after which the same events were to occur again; this period was one of 360,000 years. The number was obtained by a mere play on figures. The basal number of the Semites was six, as the system used to form their numerals shows; by multiplying it by ten (the number of the fingers) they formed the *soss*, 60; by multiplying again by ten was formed the *ner*, 600; and the square of the former gave 3600, the *sar*, or "multitude." The cosmical year was supposed to be formed of 100 *sari*, or the square of the *ner*; this was probably the number given by Berosus to the antediluvian period, 10 *sari* being attributed to each king. From this number were derived those given by the classics as the period of the Babylonian astronomical observations—720,000 years (or two cosmical years) by Epigenes, 1,440,000 (or four cosmical years) by Simplicius; the 490,000 years given by Berosus, according to Pliny, represent one cosmical year and 130,000 years, elapsed in his opinion, of the actual period. It cannot be doubted, however, that the stars have been observed in Babylonia from a very high antiquity, for we have lists of eclipses for almost every day in the year, and as these eclipses actually took place, they prove a long period of observations; some of the astronomical statements also refer to the pre-Akkadian period—that is, earlier than 7000 B.C. If the Babylonians, in spite of this long period of observations, never arrived at any correct knowledge of the motion of the planets and stars, it is no doubt due to their deficient calendar.

Omen-taking being therefore the only object of the Babylonian astronomers, or rather star-gazers, they distributed the stars and planets under the direction of certain gods, according to the influence attributed to them. This has unfortunately thrown much confusion into their nomenclature, for the name of the god is sometimes taken for that of the star which he is supposed to influence, and the same god influences several; in some cases, also, the same star is sometimes under the influence of one god,

sometimes under that of another. Besides this, we have many groups of seven stars: the seven *dibbu* or planets, the seven *masu* or double stars, the seven *sikru* or males, &c. The stars were also divided by regions—the twelve stars of the north, and the twelve stars of the south—and associated in groups of two with certain months; the months themselves were associated with certain regions, and were under the guidance of a god.

In all this we see the rudiments or rather germs of astrology; but, as astrology requires a knowledge of the movements of the planets, the Babylonians never arrived at this point—they merely took omens, and to do so they appear to have proceeded exactly as did the augurs of Rome. They described first in the sky a circle with their rod, divided this circle into eight divisions by lines passing through the centre, and then observed the position of the stars in this imaginary geometrical figure, and what kind of phenomena took place, in order to draw from them their omens. Having made his observation, the operator, or priest, then referred to the lists of omens, copies of which have come to us, to ascertain if the same celestial phenomenon had already been noted, expecting as correlative fact the same terrestrial event which had happened in the previous case.

It may be noticed, before concluding, that all the astronomical omen tablets recovered from Nineveh or Babylon are written in the Semitic language; there are no doubt a great many ideograms, but the phonetic complements, the words spelt phonetically, and the grammatical peculiarities show that the idiom used must be Semitic.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

DUBLIN.—At the Summer Commencements of the University of Dublin, held in Trinity College, Dublin, on June 27, Mr. F. W. Burbidge, Curator of the Trinity College Botanical Gardens, received the honorary degree of M.A. The Public Orator, Prof. Palmer, called attention to the benefits conferred on botanical science by Mr. Burbidge, by his travels in Borneo, and by his labours in elucidating the natural history of those classic flowers the Narcissi and the Hellebores. The honorary degree of LL.D. was conferred on Mr. Valentine Ball, F.R.S., the Director of the Science and Art Museum, Dublin, and at one time Professor of Geology and Mineralogy in Trinity College, Dublin, whose works on the geology and mineralogy of India, and researches on the identification of the animals and plants of India which were known to the early Greek authors, merited the eulogium pronounced on them by the Orator.

SOCIETIES AND ACADEMIES.

LONDON.

Linnean Society, June 6.—Mr. Carruthers, F.R.S., President, in the chair.—Dr. John Anderson, Mr. J. G. Baker, Dr. Braithwaite, and Mr. F. Crisp, were nominated Vice-Presidents.—Prof. Martin Duncan exhibited under the microscope some beautifully mounted preparations of the ambulacral tentacles of *Cidaris papillata*, and drew attention to the fact, previously unrecorded, that the tentacles of the abactinal region of the test differ in form and character from those of the actinal region. The latter have a well-developed terminal disk, and are richly spiculated; whereas the former have no disk, but terminate distally in a pointed extremity with very few spiculæ. Mr. W. P. Sladen made some remarks on the significance of this dimorphism with reference to its archaic character, and its relation to the primitive forms of Echinoids and Asteroids.—Mr. Narracott exhibited a singular fasciated growth of *Ranunculus acris*, found at Castlebar Hill, Ealing.—Mr. H. B. Hewetson exhibited under the microscope a parasite of Pallas's Sand Grouse (*Syrhaptes paradoxus*) taken from a bird shot in Yorkshire, and described as a species of *Argas*. Mr. Harting pointed out that an apparently different parasite from the same species of bird had been recently described by Mr. Pickard Cambridge (*Ann. Mag. Nat. Hist.*, May 1889) under the name *Hemaphysalis peregrinus*.—Dr. Cogswell showed some examples of Jerusalem Artichoke and Potato, to illustrate the spiral development of the shoots from right to left.—Governor Moloney, of the colony of Lagos, exhibited a large collection of birds and insects from the Gambia, the result of twelve months' collecting

¹ Abstract of the first lecture delivered by Mr. G. Bertin at the British Museum.